

1

3,259,486

METHOD OF REFINING PIG IRON

Theodor Kootz and Heinz Maas, Duisburg-Hamborn, Germany, and Erik Axel Bengtsson, Domnarvet, Sweden, assignors to Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden, a company of Sweden
No Drawing. Filed June 3, 1963, Ser. No. 284,851
Claims priority, application Germany, June 6, 1962, T 22,266

11 Claims. (Cl. 75—60)

It is known to bring a liquid bath in a container of preferably round cross section into a substantially circular swinging movement by external means and it has been proposed to refine a pig iron melt, brought into a swinging motion in this manner, to steel by blowing a gaseous oxygen carrier onto or through the melt while applying the conditions of the corresponding simple refining methods.

Special characteristics of such methods are contained in older suggestions by the applicants.

According to one suggestion the swinging motion of the bath, e.g., a pig iron bath in a container for the metallurgical treatment, especially for the refining to steel, is brought about by applying to the container which is rotatably journaled around a horizontal axis passing through or near its centre of gravity, at its top or bottom end a reciprocating movement at a constant frequency but at a different amplitude. A frequency is chosen which is in resonance with the rotating swinging movement of the bath for attaining a rotating swinging movement of the surface of the bath. For this purpose it is advantageous in a container (converter) of a cross-sectional shape other than round, suitably an elliptical cross section to arrange the initiating movement within the angle section between the longest and shortest diameters of the container section. In order to achieve an irregular wave motion of the surface of the bath the frequency of the initiating movement can be adjusted within a range of the order of 2 to 4 times as high as the one with which the circulating swinging movement is in resonance. According to another proposal the movement of the converter container can be brought about by means of a rotating disc the axis of rotation of which is perpendicular to the direction of movement of the converter, there being on the rotating disc a spindle rotatable around its axis arranged in horizontal position so that the axis of the spindle crosses the axis of rotation of the rotating disc at right angles, a nut being provided on said spindle axially displaceable through rotation of the spindle, and a lever rotatably connected at one end to said nut the other end being coupled to the converter so as to transform the rotary movement of the spindle nut into a reciprocating movement of the converter.

Further it has been stated that by inserting a spring element, e.g. a screw spring or a magnetic coil with spring action or several such elastic means, it is possible to bring about the natural vibration of the bath promoting the intermixing of metal and slag at a smaller amplitude than by non-springy-connection between propulsion means and converter.

Finally there has been suggested a method of intermixing liquid reaction baths, especially for the refining reaction in the production of steel from pig iron, in which the surface of the bath is brought into a rotating movement within a range of revolutions giving rise to the natural vibration of the bath which causes the intermixing of the constituents of the surface of the bath, particularly slag and bath, said rotating movement being caused by blowing gas onto the surface so that its impinging section describes acircular movement on the surface of the

2

bath. This method is particularly suitable for such reactions the concentration adjustment of which between the reaction phases must be in the neighborhood of equilibrium.

5 Trials carried out for the refining of pig iron to steel by blowing gaseous oxygen carriers onto a molten bath brought into a rotating swinging movement in a melting container of circular cross section by means of eccentric movement of the container gave the surprising result
10 which led to a working procedure different from the procedure of any previously known method.

When refining with oxygen blow from above it is necessary to keep the slag in liquid state during the course of the melting in order to arrive at a somewhat satisfactory concentration adjustment between metal and slag. This is especially valid for the dephosphorization reactions in the refining of pig iron rich in phosphorus. In a bottom blowing converter the formation of a liquid slag after the finish of the decarburization is necessary for this purpose. In the oxygen-converter process the dephosphorization must be carried out during the decarburization period. This necessitates maintaining a liquid slag during the decarburization. Further in these methods one or two exchanges of the slag are necessary to arrive at the demanded low phosphorus content at the desired decarburization point.

When refining pig iron to steel by blowing gaseous oxygen carriers from above the completely new knowledge was obtained that with such a movement of the bath at which natural vibrations occur which cause an intermixing of the surface layers of the bath the slag forming refining reaction and particularly the dephosphorization by means of and below solid slags proceeds not only equally well but better than with the use of liquid slags. According to this the melting process has to be adjusted so that the slag from the beginning is below its melting temperature, the liquidus point, i.e., that it is solid or predominantly solid, but towards the end when that carbon content is reached, at which it is desired to finish the refining process the slag should be liquified.

It is particularly advantageous for the attaining of such solid or substantially solid slags from the start to keep the temperature of the melt itself as low as possible and first towards the end to permit it to rise to the desired value for tapping. This is carried out in such a way that suitable cooling agents are added from the start and/or during the refining. If large additions of cooling agents bring about a commercial gain, a further advantage of a low temperature of the melt and particularly of the maintenance of a solid or substantially solid slag lies in a low attack on the lining.

The temperature of the metal melt is thereby permitted to arrive at its liquidus line and periodically even to pass a little below. Towards the end of the refining it is desirable that the temperature is high above that line. The slag temperature has thus a lower limit.

A further control lies in the adjustment of the slag composition.

When refining especially pig iron rich in phosphorus in a refining container with basic lining it is advantageous from the beginning and/or during the refining to add so much lime to the slag components formed during the refining that the total slag is supersaturated with CaO. Since the melting temperatures of the slag-polynary systems $\text{FeO} + \text{MnO} - \text{CaO} - \text{P}_2\text{O}_5$ or $\text{FeO} + \text{MnO} - \text{CaO} - \text{SiO}_2$ are essentially known it is easily possible for a man skilled in the art to choose the corresponding addition of a lime carrier.

Instead of or together with CaO also other agents, such as MgO, which increase the melting point may be added.

When refining pig iron low in phosphorus but high in silicon in a basic converter the solid slags according to

the invention also can be obtained when the slag is super-saturated with $2\text{CaO} \cdot \text{SiO}_2$, a very high melting compound. The addition of CaO carriers should then be adjusted so that this compound can be preferentially formed. A too low but also a too high lime addition decreases the melting point and could lead to liquid slags. Also in this case carriers of other basic material than CaO can be chosen which form high melting compounds with SiO_2 .

Even when refining pig iron especially low in P and S in converters with acid linings it is advantageous to work according to the invention. Then the SiO_2 -content of the slag must be so high that the slag becomes supersaturated with SiO_2 . This depends in the first place upon the relative Si content of the pig iron in relation to the contents of other slag forming accessory elements in the pig iron.

Finally, towards the end of the refining action, however, these slags have to be liquified. Insofar as the rising melting temperature, the lower carbon contents and the increasing content of ferrous oxide are not sufficient for such a liquification, fluxing slag components can then be added. For basic slags such additions are fluorspar or SiO_2 or TiO_2 or Al_2O_3 and others for acid slags bases such as CaO and MgO.

The process is completed in one step, i.e. without intermediate slag tapping. Naturally it is possible to make a break for sampling or temperature measuring or towards the end to afterrefine for correction.

Example 1

Thomas pig iron was refined to steel in an oscillating ladle of 0.8 m.³ interior volume. For the refining there was used 96% oxygen gas, as cooling agent iron ore concentrate with 67% Fe and as slag former burnt lime of the grain fraction 4-7 mm. The oxygen gas was blown through a water cooled tuyere of 15 mm. inner diameter.

Charge: 1300 kgs. Thomas pig iron.

Additions: 60 kgs. ore concentrate.

200 kgs. burnt lime.

87 Nm.³ oxygen gas.

Yield:

1122 kgs. steel

350 kgs. slag

The course of the refining is clear from the following table giving the analyses of the metal and slag samples taken out.

Period.....	0	1	2	3
Ore concentrate, kg.....		20	40	
Lime, kg.....		150	40	10
Oxygen, Nm. ³		40	37	10
Blowing time, min.....		8.0	7.5	2.5
Samples:				
Temperature of bath, ° C.....	1,120	1,360	1,610	1,565
Metal, percent:				
C.....	3.38	2.44	0.29	0.04
Si.....	0.22	0.00	0.01	
Mn.....	0.64	0.14	0.10	0.05
P.....	1.85	0.975	0.037	0.014
S.....	0.050	0.059	0.024	0.020
N.....			0.003	0.003
Slag, percent:				
CaO.....		52.7	51.4	46.3
MgO.....		3.75	2.80	2.65
SiO ₂		6.65	6.57	5.85
P ₂ O ₅		10.6	17.6	13.8
Fe (total).....		13.8	12.3	20.6

Lime in the first period was added before the beginning of the blowing and after about 6 minutes ore concentrate was added continuously. More lime was added before the start of the second blowing period whereas cooling agent was continuously added during the first two minutes of the second blowing period. The slag was molten first towards the end of the second blowing period.

Example 2

In this case a low phosphorus hot metal was blown to steel in a five-ton shaking converter using scrap as cool-

ant and burnt lime as slag former. Pure oxygen (99%) was blown through a water cooled lance with an opening of 30 millimeters.

Input:

5 4900 kgs. hot metal
100 kgs. scrap
300 kgs. lime
30 kgs. ferro manganese
314 Nm.³ oxygen

10 Output:

4300 kgs. steel
700 kgs. slag
Blowing time: 17.9 minutes

15 The course of the heat is shown in the table below:

Period No:	0	1	2
Scrap, kgs.....		100	
Lime, kgs.....		300	
Oxygen, Nm. ³		261	53
Blowing time, minutes.....		14.9	3
Sample No.....	0	1	2
Metal temperature, ° C.....	1,140	1,575	1,642
Analyses.....	0	1	2
Metal, percent:			
C.....	4.48	0.29	0.04
Si.....	0.28		
Mn.....	1.45	0.36	0.18
P.....	0.210	0.025	0.025
S.....	0.028	0.018	0.012
N.....	0.005	0.002	0.003
Slag, percent:			
CaO.....		54.4	39.6
MgO.....		2.25	2.80
MnO.....		10.8	9.24
SiO ₂		8.09	5.98
P ₂ O ₅		4.56	3.62
Fe (total).....		12.6	27.6

40 Scrap and lime were added before the start of the blowing. A thick fluid slag was formed at the end of the first period of blowing.

The advantages of this method according to the invention are many. Some of them are enumerated hereinbelow.

45 The melts are blown without any ejections and very rapidly.

The low temperature procedure demands large cooling agent additions which preferably in the form of scrap iron decrease the charge costs and increase the yield.

With the cold and solid slags the durability of the lining is very good.

50 The contents of all accessory elements in the iron, sulphur included, are very rapidly decreased to low values due to the good reactivity of the solid slags, so that the refining process is ready at any desired final carbon content.

Since one has only to go by the final carbon content the handling of the melt is very simple.

At the low temperatures the dust losses are small.

60 What is claimed is:

1. Method for refining pig iron to steel which comprises substantially continuously blowing a gaseous oxygen carrier on to a bath of molten pig iron and slag maintained in natural vibration in a melting container of round cross section by exterior means, said vibration being sufficient to cause intermixing of the surface layers of the bath, maintaining the slag in substantially solid state during the major portion of the blowing period and until a short time before attaining that carbon content at which the blowing is to be ended, liquifying said slag and shortly thereafter ending said blowing.

2. Method as defined in claim 1 in which the temperature of the bath is maintained below the pouring temperature until near the end of the blowing by the addition thereto of a cooling agent.

5

3. Method as defined in claim 1 in which the pig iron is a high phosphorus pig iron, the melting container has a basic lining, the slag is maintained supersaturated with CaO and near the end of the blowing undissolved slag constituents are caused to be dissolved in the slag by increasing the temperature of the slag.

4. Method as defined in claim 1 in which the pig iron is a high phosphorus pig iron, the melting container has a basic lining, the slag is maintained supersaturated with CaO and near the end of the blowing undissolved slag constituents are caused to be dissolved in the slag by increasing the FeO content of the slag.

5. Method as defined in claim 1 in which the pig iron is a high phosphorus pig iron, the melting container has a basic lining, the slag is maintained supersaturated with CaO and near the end of the blowing undissolved slag constituents are caused to be dissolved in the slag by adding a flux to the slag.

6. Method as defined in claim 1 in which the pig iron is low phosphorus pig iron, the melting container has a basic lining, the slag is maintained supersaturated with $2\text{CaO}\cdot\text{SiO}_2$ and near the end of the blowing undissolved slag constituents are dissolved therein by increasing the temperature of the slag.

7. Method as defined in claim 1 in which the pig iron is low phosphorus pig iron, the melting container has a basic lining, the slag is maintained supersaturated with a $\text{CaO}\cdot\text{SiO}_2$ and near the end of the blowing undissolved slag constituents are dissolved therein by increasing the FeO content of the slag.

8. Method as defined in claim 1 in which the pig iron is low phosphorus pig iron, the melting container has a basic lining, the slag is maintained supersaturated with $2\text{CaO}\cdot\text{SiO}_2$ and near the end of the blowing undissolved slag constituents are dissolved therein by adding a flux to the slag.

6

9. Method as defined in claim 1 in which the pig iron is low in P and S, the melting container has an acid lining, the slag is maintained supersaturated with SiO_2 and near the end of the blowing undissolved slag constituents are dissolved therein by increasing the temperature of the slag.

10. Method as defined in claim 1 in which the pig iron is low in P and S, the melting container has an acid lining, the slag is maintained supersaturated with SiO_2 and near the end of the blowing undissolved slag constituents are dissolved therein by increasing the FeO content of the slag.

11. Method as defined in claim 1 in which the pig iron is low in P and S, the melting container has an acid lining, the slag is maintained supersaturated with SiO_2 and near the end of the blowing undissolved slag constituents are dissolved therein by adding a flux to the slag.

References Cited by the Examiner

UNITED STATES PATENTS

879,480	2/1908	Von Maltitz	75-52
2,258,850	10/1941	Eulenstein et al.	75-52
2,668,759	2/1954	Tenenbaum	75-52
2,671,018	3/1954	Graef	75-52
2,741,554	4/1956	Rinesch	75-60
2,826,488	3/1958	Bowden	75-52
2,893,861	7/1959	Rinesch	75-52

FOREIGN PATENTS

723,615	2/1955	Great Britain.
806,776	12/1958	Great Britain.

35 BENJAMIN HENKIN, *Primary Examiner*.

DAVID L. RECK, *Examiner*.